component are preferably determined empirically for each specific CMP process by measuring the temperature of the component during polishing of a known intermediate surface **157** on a substrate and a known finished surface **157**(*a*) on a like substrate and under like operating parameters. The actual tests to empirically determine the first and second temperatures of a given polishing component for a specific CMP process may vary and are generally known to persons skilled in the art of CMP.

The preferred embodiment of the polishing machine **110** may also be used to endpoint the CMP process at a level below the top of the underlying layer **154** because the heat H_2 at the pad/substrate interface **160** also varies with the extent to which the underlying layer **154** is exposed to the polishing medium. It will be appreciated that the change in heat between the first and second heats H_1 and H_2 is also a function of the surface area of the underlying layer **154** that is exposed to the polishing medium. In many polishing processes, one area of the wafer polishes faster than another so that only a fraction of the underlying layer **154** at the finished surface **157**(*a*) is initially exposed to the polishing medium. As polishing progresses, more material is removed from the cover layer **156** to expose more of the underlying layer **154**. As a result, the change in heat when the underlying layer **154** is initially exposed to the polishing medium is often different than at subsequent points in the polishing process when a different percentage of the exposed surface area on the substrate **150** is composed of the underlying layer **154**. In a preferred embodiment, therefore, the heat sensors **170** indicate that the polishing process is at the desired endpoint when the temperature indicates that the heat H_2 at the pad/substrate interface **160** corresponds to a heat at which a sufficient percentage of the surface area on the wafer is composed of the underlying sayer **154**.

In another embodiment of the invention, a reactive agent is added to the slurry or planarizing liquid **148** to increase the difference between the heats H_1 and H_2 at the pad/substrate interface **160**. The particular reactive agent is selected according to the materials of the underlying layer **154**, the cover layer **156**, and the composition of the planarizing liquid **148**. In one embodiment, the reactive agent is HCl, NH_4OH or KOH for use with an underlying layer **154** made of tungsten, a cover layer **156** made of silicon dioxide and an H_2O_2 based planarizing liquid **148** manufactured by Rodel Corporation of Newark, Del.

A preferred embodiment of the present invention accordingly provides fast, real-time direct monitoring of the polishing status of the substrate **150**. Unlike conventional endpointing techniques that remove the substrate from the polishing pad to measure a change in the thickness of the substrate, a preferred embodiment of the present invention determines the endpoint in-situ and in real-time without removing the substrate from the polishing pad and without stopping the polishing process. A preferred embodiment of the present invention, therefore, is expected to accurately endpoint CMP processing without adversely affecting the throughput of finished substrates.

Another advantage of a preferred embodiment of the present invention is that it accurately determines the endpoint of the polishing process even though the polishing parameters may change from one substrate to the next. As discussed above in the Background section, the polishing rate of a run of substrates may change from one substrate to the next for several reasons. A preferred embodiment of the present invention is expected to accurately indicate the endpoint of the polishing process even though one or more of the polishing parameters changes from one wafer to the next because the change in heat at the pad/substrate interface **160** is a function of the composition of the planarized surface on the substrate that is exposed to the polishing medium. Therefore, it is expected that a preferred embodiment of the present invention will increase the accuracy of stopping CMP processing at a desired endpoint.

FIG. **4** is a schematic cross-sectional view of another embodiment of a polish machine **210** for polishing the substrate **150**. As discussed above with respect to FIG. **2**, the polish machine **210** has a housing **112**, a platen **120**, a substrate carrier assembly **130**, and a polishing pad **140**. The polish machine **210** also has a reacting cell **220** preferably positioned in the housing **112**, and a feed line **230** from the cell **220** to the CMP byproducts **148**(*a*) on the platen **120**. The feed line **230** is preferably movable so that it can be removed from the byproducts **148**(*a*) and/or the interior of the platen **120** during planarization when the platen **120** rotates. In operation, the CMP byproducts **148**(*a*) are pumped through the feed line **230** and into the cell **220** by a pump (not shown). Once a sufficient volume of CMP byproducts **148**(*a*) is pumped into the cell **220**, a reactive agent **240** is mixed with the CMP byproducts **148**(*a*) to detect whether material of the underlying layer **154** is present in the CMP byproducts **148**(*a*). The reactive agent **240** is preferably selected to react with the material of the underlying layer **154** in a manner that indicates the quantity of the underlying layer **154** that is present in the CMP byproducts **148**(*a*).

Many different reactive agents **240** may be added to the cell **220** to indicate the presence and quantity of material from the underlying layer **154** in the CMP byproducts **148**(*a*). Depending upon the specific reactive agent **240**, the resulting reaction may be detected by a change in temperature in the cell **220** measured by a heat sensor **170**(*d*), a change in color of the reacted CMP byproducts **148**(*a*) in the cell **220**, or other known techniques to monitor chemical reactions. One suitable reactive agent **240** to detect the presence of tungsten or compounds of tungsten in the CMP byproducts **148**(*a*) is composed of potassium chlorate ($KClO_3$) and aqua regia ($HCl+HNO_3$).

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. For example, the heat at the front of the substrate is only one characteristic of a polishing component indicative of material being removed from the planarized surface of the substrate. When the polishing component is the CMP byproducts, the characteristics of the byproducts that may be indicative of the material at the front face of the substrate include the pH of the byproducts, the conductivity of the byproducts (especially for polishing conductive layers), the color of the byproducts, and the chemical composition of the byproducts. Predetermined values of any characteristic corresponding to the endpoint may be determined in a similar manner as described above with respect to the temperature of a polishing component sensitive to the heat at the front face of the substrate. For example, the pH level of the byproducts may be determined using a calomel electrode known in the art, or the chemical composition of the byproducts may be determined by infrared spectroscopy, elemental analysis, or atomic absorption processes known in the art. Accordingly, the invention is not limited except as by the appended claims.

I claim:

1. A method for stopping polishing of a substrate at a desired endpoint, the substrate having a cover layer and an underlying layer under the cover layer, the method comprising:

monitoring a characteristic of a polishing component indicative of material being removed from a planarized surface of the substate, wherein the component comprises byproducts produced by polishing the substrate

and the characteristic is a temperature of the byproducts, and wherein the monitoring step comprises sensing the temperature of the byproducts; and

stopping removal of material from the substrate when the characteristic of the polishing component is at a predetermined value that indicates the material being removed from the planarized surface is at the desired endpoint of the substrate.

2. The method of claim 1 wherein the sensing step comprises measuring a temperature of a planarizing liquid flowing off of a polishing pad.

3. A method for stopping mechanical and chemical-mechaniical polishing of a substrate at an endpoint, the substrate having a cover layer and an underlying layer under the cover layer, and the method comprising:

monitoring heat transfer at a planarized surface of the substrate and a polishing component sensitive to heat at the planarized surface by measuring a temperature of the component, and wherein measuring the component temperature comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping polishing of the substrate when the characteristic of the polishing component is at a predetermined value that indicates the planarized surface is at the desired endpoint.

4. The method of claim 3 wherein the sensing step comprises measuring a temperature of a planarizing solution flowing off of the polishing pad.

5. A method for stopping mechanical and chemical-mechanical polishing of a substrate at an endpoint, the method comprising:

detecting a change in heat at a front side of the substrate, the heat at the front side of the substrate being different when a cover layer of the substrate engages a polishing medium than when at least a portion of an underlying layer of the substrate under the cover layer engages the polishing medium, wherein detecting a change in heat at the front side of the substrate comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping removal of material from the substrate when the heat is a predetermined value that indicates a desired portion of the underlying layer is exposed at the front side of the substrate.

6. The method of claim 5 wherein the sensing step comprises measuring a temperature of a planarizing solution flowing off of the polishing pad.

7. A method for stopping mechanical and chemical-mechanical polishing of a substrate at an endpoint, the method comprising:

measuring a temperature of a component sensitive to heat at a front side of the substrate, the component temperature being different when a cover layer of the substrate engages a polishing medium than when a portion of an underlying layer of the substrate under the cover layer engages the polishing medium, wherein measuring the component temperature comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping removal of material from the substrate when the component temperature changes from the first temperature range to the second temperature range.

8. A method of polishing a substrate, comprising:

removing material from a front side of the substrate with a polishing medium, the polishing medium being positioned at a planarizing surface of a polishing pad;

monitoring heat at the front side of the substrate, the heat at the front side of the substrate being different when a cover layer of the substrate engages the polishing medium than when at least a portion of an underlying layer of the substrate under the cover layer engages the polishing medium, wherein monitoring the heat comprises measuring a temperature of a component sensitive to heat at the front side of the substrate, the component temperature being a first temperature when the cover layer of the substrate engages the polishing medium and the component temperature being a second temperature when at least a portion of the underlying layer of the substrate engages the polishing medium, and wherein measuring the component temperature comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping removal of material from the substrate when the heat at the front side of the substrate is a predetermined value that indicates a desired portion of the cover layer has been removed from the substrate.

9. The method of claim 8 wherein the sensing step comprises measuring a temperature of a planarizing solution flowing off of the polishing pad.

10. A method of polishing a substrate, comprising:

removing material from a front side of the substrate with a polishing medium, the polishing medium being positioined at a planarizing surface of a polishing pad;

detecting a change in heat at the front side of the substrate, the heat at the front side of the substrate being in a first range when a cover layer of the substrate engages the polishing medium and the heat being in a second range when a portion of an underlying layer of the substrate under the cover layer engages the polishing medium, wherein detecting the change in heat comprises measuring a temperature of a component sensitive to heat at the front side of the substrate, the component temperature being in a first temperature range when the heat at the front side of the substrate is in the first heat range and the component temperature being in a second temperature range when the heat at the front side of the substrate is in the second heat range, and wherein measuring the component temperature comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping removal of material from the substrate when the heat at the front side of the substrate is in the second range.

11. The method of claim 10 wherein the sensing step comprises measuring a temperature of a planarizing solution flowing off of the polishing pad.

12. A method of polishing a substrate, comprising:

removing material from a front side of the substrate with a polishing medium, the polishing medium being positioned at a planarizing surface of a polishing pad;

measuring a temperature of a component sensitive to heat at the front side of the substrate, the component temperature being different when a cover layer of the substrate engages the polishing medium than when at least a portion of an underlying layer of the substrate under the cover layer engages the polishing medium, wherein measuring the component temperature comprises sensing a temperature of byproducts produced by polishing the substrate; and

stopping removal of material from the substrate when the component temperature changes from the first temperature range to the second temperature range.

13. The method of claim 12 wherein the sensing step comprises measuring a temperature of a planarizing solution flowing off of the polishing pad.

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